

Drive circuit for an LED array

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Technical field

The present invention relates to a drive circuit for an LED array which comprises a first LED cluster and at least one second LED cluster, a switch being arranged in series with each LED cluster, and each LED cluster having a supply terminal via which it can be connected to a supply voltage, it being possible to drive each switch so as to permit a current flow in the associated LED cluster, having a control loop which is designed to drive the switch of the first LED cluster so as to achieve a constant mean value of the current flowing through the first LED cluster, the control loop being designed to drive at least one switch of a second LED cluster. It relates, moreover, to a method for operating an LED array which comprises a first LED cluster and at least one second LED cluster, a switch being arranged in series with each LED cluster, and each LED cluster having a supply terminal via which it can be connected to a supply voltage.

Prior art

The invention is concerned with driving LEDs. It is normal for this purpose to use series resistors or current sources which limit and/or control the current through the LED. The LEDs are generally interconnected to form a cluster, that is to say a cluster comprises a series circuit of a plurality of LEDs. A plurality of LED clusters must be connected in parallel, that is to say be combined to form an array, depending on the size of the area to be lit or backlit. There is the basic problem here that a status terminal of the drive circuit is intended to supply a corresponding

indication as soon as a fault has occurred in one or more LED clusters.

- A first solution to this problem that is known from the prior art and comes from ST Microelectronics AG consists in interconnecting the entire LED array to form a single LED cluster. It is disadvantageous in this solution that such an LED cluster requires a substantially higher supply voltage in order to reach the LED cluster voltage, that is to say the sum of all the LED forward voltages. As soon as a fault occurs, the complete LED array is de-energized, that is to say it no longer shines.
- 15 A second solution that is known from the prior art and comes from Infineon Technologies AG consists in controlling and monitoring each individual LED cluster using a dedicated LED drive block. Since an LED array usually consists of a plurality of LED clusters, this invention is attended by the disadvantage that a plurality of LED driver blocks are required therefor. All the LED driver blocks are connected together to a single status terminal, and so it cannot be determined exactly how many LED clusters have failed. The use of a 20 plurality of LED driver blocks is not desired, since this has a disadvantageous effect on the costs.
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A further solution to the above problem, which is known from the prior art, is provided by the applicant of the present invention (DE19930174; Biebl) and functions as follows:

- firstly, the principle of pulsed current control is explained with reference to figure 1: a series circuit 35 of a plurality of LEDs, D1 to D4, is connected, on the one hand, to a supply voltage  $U_{\text{Batt}}$  via a switch S1, and on the other hand to frame via a measuring shunt  $R_{\text{shunt}}$ . The voltage  $U_{\text{Shunt}}$  dropping across the resistor is fed to an integrator 10 which provides at its output a mean

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value of the voltage present at the input. This voltage is fed to a controller 12 which also receives as input signal a reference voltage  $U_{Ref}$  which corresponds to a mean desired value of the current  $I_{Led}$  through the LEDs,  
5 D1 to D4. The control voltage  $U_{Regel}$  provided by the controller 12 at its output is supplied to the positive input of a comparator 14, there being present at its negative input a delta voltage  $U_D$  which is provided by a triangle generator 16. The output signal of the  
10 comparator 14 is used to drive the switch S1. As emerges from the graph in the right-hand half of figure 1, the signal driving the switch S1 is a pulsed signal, recognizable from the squarewave function of the LED current  $I_{LED}$ . This arrangement ensures that the  
15 current  $I_{LED}$  flowing through the LEDs is controlled to a value correlated with the voltage  $U_{Ref}$ .

Shown schematically and by way of example in the right-hand half of figure 2 are three such circuits,  
20 illustrated in figure 1, with pulsed current control, specifically the blocks 18, 20, 22. The supply voltage, the individual LEDs and, likewise, the resistors  $R_{Shunt}$  are omitted for reasons of clarity. If each of the blocks 18, 20, 22 comprises an LED cluster, an LED  
25 array can be realized by such an interconnection. A triangle generator 24 applies a clock signal 26 to a counter 28 which is applied to a multiplexer 30. The clock signal causes the multiplexer 30 to sample the control voltages of the three blocks 18, 20, 22  
30 sequentially and feed them to a fault detection logic circuit with a comparator 32 and a flip-flop 34. As soon as one of the control voltages  $U_{Regel\ 1}$ ,  $U_{Regel\ 2}$ ,  
35  $U_{Regel\ 3}$  is lower than a prescribed threshold-value voltage  $U_{sw}$ , the comparator 32 generates a signal to the flip-flop 34 so as to generate at the Q output of the flip-flop 34 a signal which indicates a fault in one of the LED clusters of the blocks 18 to 22. Here, only the blocks 18 to 22 are mentioned by way of example, it being possible, of course, as indicated by the lines of

dashes, for further blocks to be part of the same LED array.

- The problem with this solution is, firstly, the  
5 additional outlay for a counter 28 and a multiplexer 30  
and, on the other hand, the fact that a plurality of  
LED driver blocks are required in the case of larger  
LED arrays, since the number of current control loops  
per LED driver block is limited, for example to eight.  
10 The use of a plurality of LED driver blocks is  
reflected, in turn, disadvantageously in the price.

In addition to the disadvantages mentioned, in the case  
15 of the solutions addressed there is a further  
disadvantage that a fault signal is output immediately  
as soon as a fault has occurred. This is necessary,  
however, only if, as in the case of the first named  
solution, the complete LED cluster has failed. With  
regard to specific fields of application of LED arrays,  
20 for example in the vehicle sector as taillights, this  
would again justify the use of an incandescent bulb. In  
the case of an incandescent bulb, there also exists  
only two states of incandescent bulb intact and  
incandescent bulb not intact. The advantage of using  
25 LEDs in this sector resides, however, in the fact that  
in the event of failure of an LED cluster the light is  
capable of continuing to be operated if sufficient  
other functioning LED clusters are still present -  
although with somewhat diminished luminance - but, if  
30 suitably dimensioned, still above a limiting value  
prescribed by statute.

#### Summary of the invention

- 35 The object of the present invention therefore consists  
in developing the drive circuit named at the beginning  
for an LED array in such a way that the further  
operation of the LED array is ensured in conjunction  
with a cost-effective realization if the entire

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luminance of the LED array lies above a prescribable value.

This problem is solved by a drive circuit having the  
5 features of patent claim 1, and by a method for  
operating an LED array having the features of patent  
claim 17.

The point of departure is a patent application of the  
10 present applicant entitled "Ansteuerschaltung für LED  
und zugehöriges Betriebsverfahren" ["Drive circuit for  
LEDs and associated method of operation"] (application  
No. DE19950135.1; Biebl; not yet laid open), in the  
15 case of which a plurality of LED clusters are operated  
in a cascade arrangement. In this case, a higher-level  
LED cluster is denoted as master cluster, and its  
average current is fed to a control loop, the drive  
signal of the master cluster also being used to drive a  
plurality of lower-level LED clusters, what are termed  
20 slave clusters. Starting from the teaching of the  
application just mentioned, the finding of the  
invention consists in that the above object can be  
achieved when the total current through all the slave  
clusters is measured and this current is compared  
25 against a prescribable desired value. No fault message  
is generated as long as the total current lies above  
the threshold value despite failure of individual slave  
clusters. A fault signal is not generated until the  
prescribed threshold value is undershot, which is the  
30 same as saying, for example, that the diminished  
luminance now no longer corresponds to the statutory  
stipulations.

This realization offers the advantage that the entire  
35 LED array can be operated despite failure of individual  
LED clusters, that the fault detection logic circuit  
can be kept very simple, in particular need be provided  
only once, and, finally, that the LED array with an  
arbitrary number of LED clusters can be monitored by

the fault detection device. The only limiting factor is the driver for generating the drive signal for the switch of each LED cluster.

- 5 In a particularly preferred embodiment, the desired magnitude can be set by a user. A user is able by means of this measure to determine himself how many LED clusters may fail before the fault signal is generated and thereby informs the user of a failure. Furthermore,  
10 the comparison unit is preferably to be designed to output an information signal in the event of undershooting of the desired magnitude by the actual magnitude. This information signal can then also be used, for example, for the purpose of informing a user  
15 to switch over to another array, etc.

- Furthermore, the drive circuit according to the invention preferably comprises a monitoring unit with which the current flow through the first LED cluster can be monitored. This is particularly advantageous because, after all, the slave clusters are also driven with regard to what is termed the master cluster. Specifically, the current flow through the master cluster serves as input signal of the control loop, which also drives the slave clusters. In the event of failure of the master cluster, the risk would therefore exist that all the slave clusters would also be destroyed by being driven incorrectly. On the other hand, in the event of a fault having been detected as occurring in the master cluster, it is possible to switch over to a standby control loop, for example, to a control loop provided for a slave cluster, so that this slave cluster can then become the master cluster.  
30  
35 The monitoring unit is therefore preferably designed in such a way that the control loop is disconnected when a current flow which is outside a prescribable tolerance range, for example in the event of no current flow at all, is determined in the first LED cluster.

The drive circuit also preferably comprises an undervoltage detection device which is designed to output an undervoltage warning signal when the supply voltage falls below a prescribable value. Specifically, uncontrolled processes can result when the supply voltage of the circuit, the vehicle voltage in an automobile, for example, approaches the cluster voltage of the LEDs, that is to say the sum of all the LED forward voltages. In particular, the prescribed desired magnitude can be unintentionally modified such that the comparison unit wrongly outputs an information signal. This is preferably achieved by virtue of the fact that the supply voltage is compared with a reference voltage which is preferably equal to or greater than the sum of the forward voltages through all the LEDs of a cluster. As long as the supply voltage is higher than the reference voltage, no undervoltage warning signal is output. This measure permits the drive circuit to remain active in the event of noncritical drops in the supply voltage.

The drive circuit is preferably designed such that this prescribable value can also be set manually or  
25 prescribed permanently.

In accordance with the particularly preferred exemplary embodiment, the drive circuit further comprises an output unit to which the information signal and/or the  
30 undervoltage warning signal can be transmitted. This opens up the possibility that in the event of receipt of the information signal the output unit relays the latter, for example makes it available as fault signal to a user, only when no undervoltage warning signal has  
35 been transmitted.

The output unit is therefore preferably designed such that in the event of receipt of the undervoltage warning signal it deactivates itself for a

predetermined time or for the duration of reception of the undervoltage warning signal such that during a time interval in the course of which the supply voltage has dropped below a critical value, the output unit does  
5 not produce any incorrect results.

The output unit preferably has at least one transistor which is located in an open collector circuit and whose base is connected to the comparison unit for the  
10 purpose of transmitting the information signal, and/or is connected to the undervoltage detection device for the purpose of transmitting the undervoltage warning signal. An open collector circuit offers the advantage that the collector of the transistor is drawn to frame  
15 upon the occurrence of the information signal and/or the undervoltage detection signal. The signal present at the collector can in this way be connected simply to any desired realizations of a fault evaluation circuit. For example, this opens up the possibility of  
20 interconnecting other output units, which are likewise realized in an open collector circuit, via the respective collectors. As soon as a collector is drawn to frame, that is to say a signal which switches the respective transistor into the conductive state, is  
25 present at the base of the transistor, a common display can be activated for all the output units.

In a particularly preferred exemplary embodiment of the invention, the drive circuit further comprises a  
30 closing delay device which is designed to deactivate the output unit for a predetermined time after the closure of the drive circuit. Such a closing delay device acts advantageously against uncontrolled switching processes which are associated with the  
35 closure, chiefly inside the control loop.

The output unit can comprise a flip-flop, it being possible to connect the base of the transistor to the output of the flip-flop, and the set input of the flip-

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- flop to the undervoltage detection device in order to transmit the undervoltage warning signal, and/or to connect it to the comparison unit in order to transmit the information signal. The use of a flip-flop prevents 5 a sporadic fault signal, for example in the case of contact problems. That is to say, once set, a fault signal is retained as long as the drive circuit is closed, that it to say activated.
- 10 It is particularly advantageous in this context when the closing delay device is designed to apply a closing delay signal to the reset input of the flip-flop of the output unit over the duration of the closing delay. It is possible very simply in this way also to use the 15 flip-flop for the purpose of preventing an output of a fault signal via the output unit during a predetermined time interval after the closure of the drive circuit.
- 20 The drive circuit according to the invention is not limited only to the clocked operation of the LED drive, but is just as suitable for a DC operation of LEDs. Determined in the first case mentioned as actual magnitude is a mean value of the sum of the currents through at least two, in particular through all of the 25 second LED clusters, in order to make a comparison against the desired magnitude.
- The above object is also achieved by a method for operating an LED array which comprises a first LED 30 cluster and at least one second LED cluster, a switch being arranged in series with each LED cluster, and each LED cluster having a supply terminal via which it can be connected to a supply voltage. In this method, the switch of the first LED cluster is driven with a 35 drive signal so as to achieve a constant mean value of the current flowing through the first LED cluster, at least one second LED cluster being driven with the same drive signal. The sum of the currents through at least two, in particular through all of the second LED

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clusters is measured as actual magnitude, the actual magnitude subsequently being compared with a prescribable desired magnitude.

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#### Description of the drawings

Further advantageous embodiments are defined in the subclaims. Exemplary embodiments of the invention are described below in more detail with reference to the  
10 attached drawings, in which:

figure 1 illustrates a circuit arrangement, known from the prior art, for driving an LED cluster with pulsed current control;

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figure 2 illustrates a drive circuit, known from the prior art, for a plurality of LED clusters with a multiplexer;

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figure 3 illustrates a first exemplary embodiment of a drive circuit according to the invention with detection of the total current of the slave clusters;

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figure 4a illustrates the characteristic of the fault signal in the event of occurrence of a fault of decisive importance;

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figure 4b illustrates the time characteristic of the voltage  $U_{\text{Mess}}$  in the event of failure of individual LED clusters in the exemplary embodiment of figure 3;

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figure 5 shows a detailed illustration of the embodiment of figure 3; and

figure 6 shows a schematic illustration of a block diagram of an embodiment of the fault diagnosis for a drive circuit according to

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the invention.

Identical reference symbols are used throughout below for identical and equivalent elements of the various  
5 exemplary embodiments.

In the drive circuit illustrated in figure 3, a first LED cluster 40 with two LEDs D1, D2 is denoted as master cluster. A plurality of second LED clusters 42,  
10 44 with LEDs D3, D4, D5, D6 are denoted as slave clusters. Of course, a multiplicity of LEDs can be arranged per cluster instead of the two LEDs shown by way of example. This is limited essentially by whether the battery voltage  $U_{Batt}$  used for the supply suffices  
15 in order to apply the sum of the LED forward voltages.

The current flow through the master cluster 40 is detected by means of a resistor  $R_{Shunt}$ , the voltage  $U_{Shunt}$  dropping across the resistor  $R_{Shunt}$  being fed to an LED drive circuit 46. The latter supplies the drive clock pulse CLK for the switch S1 of the master cluster 40, as well as for the switches S2, S3 of the slave clusters 42 and 44. The total current through the slave clusters is determined via a resistor  $R_{Mess}$ , the voltage  
20  $U_{Mess}$  dropping across the resistor  $R_{Mess}$  being fed to the diagnosis unit 50. The latter continues to receive the battery voltage  $U_{Batt}$  as well as a signal 48 fed by the LED drive unit 46. The diagnosis unit 50 for its part supplies a signal 58 to the LED drive unit 46. The  
25 signals 48 and 58 are described further below in yet more detail, as is the design of the diagnosis unit 50. The output signal of the diagnosis unit 50 is applied to the base of a status transistor ST1 in an open collector circuit. An item of information on the status  
30 of the LED array is provided at a collector of the transistor ST1.  
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Figure 4b shows the time characteristic of the voltage  $U_{Mess}$  dropping across the resistor  $R_{Mess}$ . Also plotted is

- a voltage  $U_{OL}$  defined by a user, which prescribes a desired value against which  $U_{Mess}$  is compared. The failure, taking place at the instant  $t_1$ , of a first slave cluster exerts no influence, since the voltage
- 5      5       $U_{Mess}$  is higher than  $U_{OL}$  even after this failure. It is the failure of a second slave cluster at the instant  $t_2$  which is the first to cause  $U_{Mess}$  to undershoot the voltage  $U_{OL}$ , and this leads to the generation of an information signal 47, see figure 4a. The status signal
- 10     10     at the collector of the status transistor ST1 does not go from high to low until the failure of the second slave cluster at the instant  $t_2$ , that is to say at the instant at which  $U_{Mess}$  undershoots  $U_{OL}$ .
- 15     The LED drive unit 46 and the diagnosis unit 50 of figure 3 are illustrated in more detail in figure 5. A triangle generator 52 supplies a triangular signal  $U_D$  to the negative input of a comparator 54. As input variable, a control unit 56 receives, on the one hand,
- 20     20     the voltage  $U_{Shunt}$  dropping across the resistor  $R_{Shunt}$ , as well as a reference voltage  $U_{Ref}$  with which the mean value of the current  $I_{LED}$  through the LEDs of the master cluster 40 is set. Since the switch S1 is designed in this case as PNP transistor and the delta voltage  $U_D$  is
- 25     25     fed to the comparator 54 at the negative input thereof, in the case when the current  $I_{LED}$  through the master cluster is too low the controller 56 generates a lower control voltage  $U_{Regel}$  at its output. The controller 56 increases the voltage  $U_{Regel}$  in the case when the current
- 30     30      $I_{LED}$  is too high. In the case of a fault in the master cluster 40 which prevents a current flow  $I_{LED}$  through the master cluster 40,  $U_{Regel}$  would therefore become very low and the consequence of this would be that the switches S2, S3 of the slave clusters 42, 44 would be
- 35     35     driven by the comparator 54 in such a way that they would open fully. The result of this would be that the slave LED clusters D3, D4, D5, D6 would be at the full supply potential  $U_{Batt}$ , and this could result in destruction of the LEDs. In order for this not to

occur, the voltage  $U_{Regel}$  is fed as signal 48 to the diagnosis unit 50 which is designed in such a way that a drop in  $U_{Regel}$  below a prescribable threshold value is recorded and switches off the triangle generator 52 via  
5 a connection 58.

In addition to the already mentioned safety measures,  
figure 6 shows in a schematic illustration a general  
10 view of two further ones which can be realized in the  
drive circuit according to the invention. The diagnosis  
unit 50 is separated into a block 50a, a block 50b and  
a block 50c in order to separate the individual  
functions. The voltage  $U_{Mess}$  dropping across the  
15 resistor  $R_{Mess}$  is integrated in an integrator 60 in the  
block 50a, that is to say the mean value is formed, and  
the output signal of the integrator 60 is fed to a  
comparator 62. The comparator 62 receives at its other  
20 input the voltage  $U_{oL}$  obtained by a voltage divider,  
which comprises the resistors  $R_1$  and  $R_{oL}$ , from the  
voltage  $U_{Ref}$ . The comparator 62 provides the signal 78  
at its output.

A block 64 serves to detect undervoltages.  
Specifically, as soon as the supply voltage  $U_{Batt}$  of the  
25 circuit approaches the cluster voltage of the LEDs,  
that is to say the sum of all the LED forward voltages,  
uncontrolled processes can occur during the fault  
diagnosis. For this purpose, the supply voltage  $U_{Batt}$  is  
compared in a comparator 56 against a reference voltage  
30  $U_{Ref1}$ . Fixing the voltage  $U_{Ref1}$ , that is to say the  
undervoltage limit, can be performed by a voltage  
divider which is preferably located completely outside  
the undervoltage detection unit 64. Alternatively, the  
voltage divider can be realized by locating a resistor  
35 in the circuit and an adjustable resistor outside. The  
voltage  $U_{Ref1}$  can then be set by a user via the external  
resistor. However, it is also possible to provide, for  
example when applying the drive circuit in the  
automobile sector, where the overvoltage limit is

prescribed (this being 9 V in the 14 V/12 V vehicle network, and 30 V in the 42 V vehicle network), for the capability for manual setting to be dispensed with in order to save costs, and for  $U_{Ref}$  to be fixed with  
5 regard to the vehicle network voltage. The undervoltage detection unit provides a signal 76 at its output.

The control voltage  $U_{Regel}$  is fed to the block 50b and compared in a comparator 68 against the reference  
10 voltage  $U_{Ref2}$ . If the voltage  $U_{Regel}$  is lower than the voltage  $U_{Ref2}$ , the comparator 68 supplies a signal to a flip-flop 70 whose output signal 72 can, for the purpose of preventing a destruction of the LEDs in the slave clusters, be used to disconnect the entire drive  
15 circuit, or to trigger a master switchover in the case of which a slave cluster is made into the master cluster. The block 50b is also fed the signal 76 of the undervoltage detection unit 64 in order to prevent erroneous generation of the output signal 72 in the  
20 case when the supply voltage  $U_{Batt}$  has dropped too far. The reason for this is that the reference voltage  $U_{Ref2}$  is frequently obtained from the supply voltage  $U_{Batt}$  and a comparison with the voltage  $U_{Regel}$  could lead to incorrect results in the event of occurrence of an  
25 undervoltage.

A closing delay for the drive circuit is realized with the arrangement in block 74 in order to prevent uncontrolled switching operations in conjunction with  
30 closing the drive circuit. It generates a signal 80 at its output.

Just like the output signal 78 of the block 50a, and the output signal 80 of the closing delay circuit 74,  
35 signal 76 is fed to the block 50c, which drives the status transistor ST1. It is ensured in block 50c that a signal to the status transistor is generated only when the drive circuit is not in a predetermined time interval after the closure, if no undervoltage is

present and, at the same time, the voltage  $U_{\text{Mess}}$  is lower than  $U_{\text{OL}}$ . The block 50c comprises a flip-flop 88, the signal 76 and the signal 80 being applied in an OR'd fashion, to the reset input R of the flip-flop 88,  
5 while the signal 78 is applied to the set input S of the flip-flop 88. A sporadic fault signal in the event of possible contact problems is prevented by the use of the flip-flop 88. In the present case, once it has been set, a fault signal is retained as long as the drive circuit is connected. An enable input (not illustrated)  
10 can be provided for resetting a set fault signal.

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